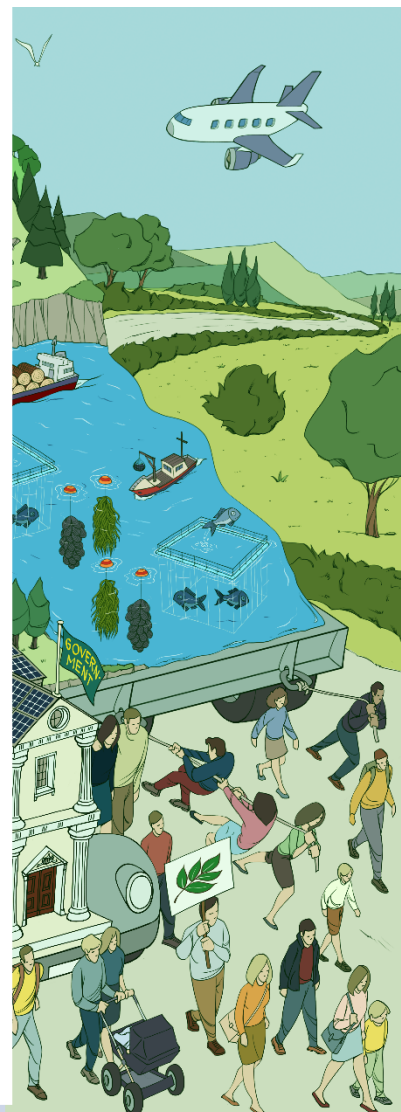
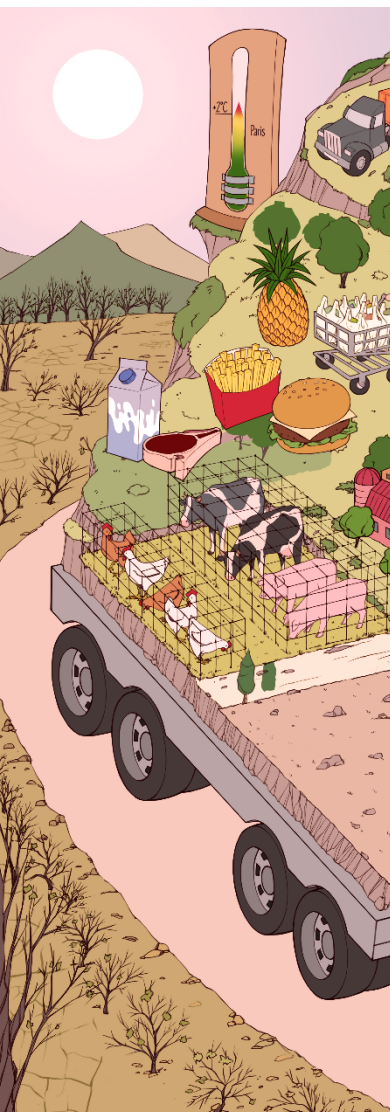


Future transitions for the Bioeconomy towards  
Sustainable Development and a Climate-Neutral Economy

# Foresight Scenarios for the EU bioeconomy in 2050

Knowledge Synthesis and Foresight Work Package 1 - Network of Experts

The European Commission's Knowledge Centre for Bioeconomy



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<sup>1</sup> A list of the foresight workshop participants is given in Annex 2 (Table 5).

## Abstract

The 2018 EU Bioeconomy Strategy aims to develop a circular, sustainable bioeconomy for Europe, strengthening the connection between economy, society, and environment.

It addresses global challenges such as meeting the Sustainable Development Goals (SDGs) set by the United Nations and the climate objectives of the Paris Agreement.

A circular, sustainable bioeconomy can be a **core instrument** for the **Green Deal** in the post-COVID-19 era, making the EU more sustainable and competitive.

In this context, the EC (Joint Research Centre in collaboration with DG Research and Innovation) created an ad-hoc external Network of Experts (NoE) through individual contracts to contribute to the EC's Knowledge Centre for Bioeconomy with forward-looking analysis needed for exploring possible scenarios towards a sustainable, clean, and resource-efficient bioeconomy, with a focus on climate-neutrality and sustainable development. The first work package concerned knowledge synthesis and foresight.

This report presents the results of a **collaborative foresight process** which elaborated four scenarios for the future EU bioeconomy until 2050:

**Scenario 1: Do it for us** - proactive policy, Paris target nearly achieved (2 °C global temperature increase by 2100), no societal change (Business As Usual trend for consumption)

**Scenario 2: Do it together** – integrative policy, Paris target fully achieved (1.5 °C global temp. increase by 2100), fundamental societal change (towards sustainable consumption)

**Scenario 3: Do it ourselves** - societal action, Paris target missed (global temperature increase 2.5 °C by 2100), fundamental societal change (towards sustainable consumption)

**Scenario 4: Do what is unavoidable** - reactive policy, Paris target clearly missed (3.5 °C global temperature increase by 2100), no societal change (Business As Usual trend for consumption)

Finally, this report presents **initial reflections on transition pathways** gained from these scenarios in 2050, and **insights for the future of the bioeconomy** in Europe, and abroad, with a focus on implementing a circular, sustainable, and transformative **BioWEconomy**, not only in the EU, but globally.

## Executive Summary

The updated EU Bioeconomy Strategy adopted in October 2018 aims to develop a sustainable bioeconomy for Europe, which will foster the societal transition towards circular and low carbon economies through provision of green and circular alternatives to the linear fossil-based production and consumption patterns.

Bioeconomy has wide sectoral coverage and unique potential to link primary production at local level with multiple industrial processes and products under safe and sustainable operating boundaries. It can strengthen local economic resilience and offer new opportunities for income and jobs through increased innovation, circularity, and market diversification.

A circular sustainable bioeconomy can therefore be a **core instrument** for the **Green Deal** in the post-COVID-19 recovery, making the EU more resilient and competitive. It can address global challenges such as meeting the Sustainable Development Goals (SDGs) set by the United Nations and the climate objectives of the Paris Agreement and improve social resilience alongside the environment and the economy.

Extensive knowledge and foresight capacities are however needed to inform the direction of future research and innovation programmes and policy making, but also modelling needs to integrate all three sustainability dimensions to provide a thorough assessment. In this context, the European Commission (JRC in collaboration with DG RTD) created an ad-hoc external **Network of Experts** (NoE) through individual contracts to contribute to the European Commission's Knowledge Centre for Bioeconomy with forward-looking analysis needed for exploring possible scenarios towards a sustainable, clean, and resource-efficient bioeconomy, with a focus on climate-neutrality and sustainable development.

Following the foresight process, the scenarios have been **co-created with stakeholders** across the policy, industry, and academia during two dedicated workshops. The scenarios represent a set of **plausible futures** and are consistent with the combinations of developments that build multidimensional pictures of the future European bioeconomy.

They are formed across a vertical and a horizontal axis:

- The vertical axis characterises the capacity of the EU political system to implement consistent, coherent, and effective policies that are directed towards the achievement of the **climate-neutrality goal and the SDGs**, within the EU and contributing to achieving these goals outside.
- The horizontal axis characterises the attitude of the **society towards change**, especially related to consumers' lifestyles, coherent with SDG 12 (Responsible consumption and production).

Four **scenario narratives** have been developed for the 2050 EU bioeconomy, with 2030 as an interim step:

- **Scenario 1 'Do it for us'**: A consistent and coherent set of policies is designed, and implemented to foster radical change in the supply systems, but **society resists** significant changes in demand (consumption). The climate target is nearly achieved.
- **Scenario 2 'Do it together'**: Both the political system and society are aligned and proactive to achieve climate-neutrality and the SDGs. The climate target is fully achieved.
- **Scenario 3 'Do it ourselves'**: The political system shows an incapacity to implement significant climate and SDG policies. However, consumers change their attitudes and behaviour under the thrust of increasingly influential social movements and the aftermath of a series of dramatic crises. The climate target is missed.
- **Scenario 4 'Do what is unavoidable'**: Lifestyles do not change significantly from Business As Usual (BAU) patterns (but levels rise), and the political system is not able or supportive to implement/enforce proactive policies, limiting itself to adopt – with some delay – measures in reaction to crises. The climate target is clearly missed.

**Initial reflections** on **transition pathways** gained from these scenarios in 2050, with a focus on potential 2030 milestones, are:

- For Scenarios 1 and 2, key milestones are the **New Green Deal** (with expanded funds for e.g., massive extension and transformation of **infrastructure**), strengthening the ambition of the **next Common Agricultural Policy (CAP) reform**, to engage in bi- and multilateral **trade policies** to introduce agreed sustainability standards at least for bioeconomy-related commodities, implement **border adjustments** for the EU carbon tax to level the playing field between the EU



economy and its trade partners, and implement bioeconomy investments into the [EU Taxonomy](#) (including 'crowdfunding').

- For Scenarios 2 and 3, strengthening the [cultural and social activities](#) is fundamental to foster the demand-side transformation, especially in food and transport systems. In Scenario 3, this will be a bottom-up dynamic, as EU (and Member State) policies remain reactive. In Scenario 2, this must be achieved through pro-active EU policy concerning consumers (better and clear [labelling](#) of sustainable products, taxes for non-renewable products and quota systems) well before 2030 to allow for consumers' behaviour adaptation. Inclusive EU policies towards communication and education on the '[BioWEconomy](#)' are crucial and should [partner](#) with actors from [culture and arts](#) to reach out more effectively to the EU citizens. A key milestone for this could be a series of media campaigns and (online) EU 'town hall meetings'.
- Scenario 2 also [requires policy integration](#) both horizontally (across sectors), and vertically (EU, Member States, cities and regions, citizens).
- For Scenario 4, there are no milestones, as it represents reactive policies and inertia on the business and citizen side. This 'muddle through' is an extension of past policies and may describe the future [if no further action](#) and change is pursued.

First [insights for the future of the bioeconomy](#) in Europe, and abroad, are:

- In **Scenario 1 'Do it for us'**, policy focuses on the [supply side](#) only, which is effective to mitigate and adapt to [climate change](#) but creates [strong trade-offs](#). Rising demands require more expensive supply-side measures than in Scenario 2, implying risks for social acceptance. A post-2030 '[New Green Deal](#)' is crucial to foster innovation, and (some) collaboration with Member States. The [social](#) side of sustainability, and outside of EU impacts, are problematic, though.
- **Scenario 2 'Do it together'** follows an [integrative approach](#) and delivers best but is also [most challenging](#). Bioeconomy policy must reach out to society, be inclusive towards Member States ([diversity](#)), and social movements. It also requires the post-2030 '[New Green Deal](#)'. The bioeconomy is built from the ground (bottom-up) and collaborative top-down (clusters and networking), also with [partners outside](#) of the EU.
- **Scenario 3 'Do it ourselves'** focuses on the [demand side](#), with restricted effectiveness for [climate change](#) adaptation and mitigation by missing policy support and lagging transformation of businesses. Strong [socio-cultural movements](#) based on local action & networking are fundamental. Awareness-raising and education are [not only](#) a matter for (Member) States, but part of broad [socio-cultural](#) activities.
- **Scenario 4 'Do what is unavoidable'** is the most unfavourable, but may well be the most realistic, given the trends over the last three decades. A 'muddle-through' logic of short-sighted, uncoordinated, and non-integrated policies along levels as well as themes and sectors will cause much pain and losses.

Scenario 2 as the [combination](#) of Scenarios 1 and 3 gives the best overall results, avoids negative trade-offs, and also meets the SDGs related to the bioeconomy by 2030. In that, its [integrative approach](#) is the key: neither supply-side policies nor demand-side societal action are enough, and policy coherence across sectors as well as actors (Member States, business, civil society) can be achieved only through integration.

Here, the European Green Deal is an important [first step](#), and together with the EU budget and its COVID-19 recovery fund can align Member States and businesses in the coming years.

Yet, Scenario 2 asks for more: A more ambitious post-2030 '[New Green Deal](#)' for [both](#) the supply- and demand-side. This implies to support civil society and societal movements, and to be more inclusive to and collaborative with culture and arts: Innovation and transformation in Scenario 2 concern both technology [and](#) society.

For this, there is not yet a clear pathway nor a formula to draw from – it will require [exploration](#) and [experiments](#), exchange among pioneer actors, open reflection on possible alternatives and lessons learnt, and outreach to many actors for inclusion.

## 0 Background

This report introduces the foresight process on [Future transitions for the bioeconomy towards sustainable development and a climate-neutral economy](#), its scenario logic, and presents scenario narratives developed from this logic, and respective results.

To allow for easy reading, each narrative starts with a short summary of key drivers and outcomes<sup>2</sup>.

As time horizons, the scenario narratives address 2030, as an intermediate time point, and 2050 as the long-term time horizon.

### 0.1 The foresight process

The objective of this foresight exercise is to develop scenarios of how the EU bioeconomy could evolve by 2050 to address the question: [How can the EU bioeconomy best contribute to specific SDGs and the transition towards a climate-neutral economy by 2050?](#)

*"[The] Commission has a strong mandate to put strategic foresight at the heart of EU policymaking. Strategic foresight can help build collective intelligence in a structured manner to better chart the way forward for the twin green and digital transitions and to recover from disruptions." (EC 2020a)*

Foresight is a systematic participatory process, creating collective intelligence about the medium- to long-term future. It can support policymaking by informing short-term decisions to ensure they are coherent with long-term objectives.

The development of scenarios is one of the techniques used in foresight. It identifies the relevant [drivers of change](#) of the system being considered and analyses the interplay between the respective drivers. This helps to develop a deep understanding of the logic of various possible future developments.

A 360° perspective covering societal, technological, ecological, economic, and political drivers and zooming in from overarching to bioeconomy-specific factors helps avoid tunnel thinking.

Scenarios are plausible and consistent with the combinations of developments that build multidimensional pictures of the future of bioeconomy in the EU. They are laying out a variety of plausible actions to feed strategic reflections. The scenarios presented in this report describe possible plausible paths of the bioeconomy from today to 2050. The alternative paths imply different strategic and political action needs to contribute best to specific SDGs and the transition towards a climate-neutral economy by 2050.

The ad-hoc Network of Experts had previously developed a knowledge synthesis on the bioeconomy system, trends, and perspectives, addressing key questions central to the future development of the bioeconomy (Fritsche et al. 2020).

This synthesis was a core input to the foresight exercise that was supported more than 50 experts (in addition to the ad-hoc Network of Experts) selected to cover in a balanced way the different aspects of the bioeconomy. Most of them participated in both workshops and some in only one of them.

During the 1<sup>st</sup> Foresight Workshop on 23 - 24 June 2020, the experts identified the main drivers of change in the EU bioeconomy in a time horizon 2030 to 2050. After the drivers' identification, participants ranked the drivers according to their importance (i.e., their power to influence the future of the bioeconomy) and their uncertainty (i.e., the degree of uncertainty about the driver's future development path until 2050).

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<sup>2</sup> For a synopsis of key drivers and trends for the supply side of all scenarios see Table 3, and for demand-side drivers, trends and outcomes see Table 4 (both in Annex 1).

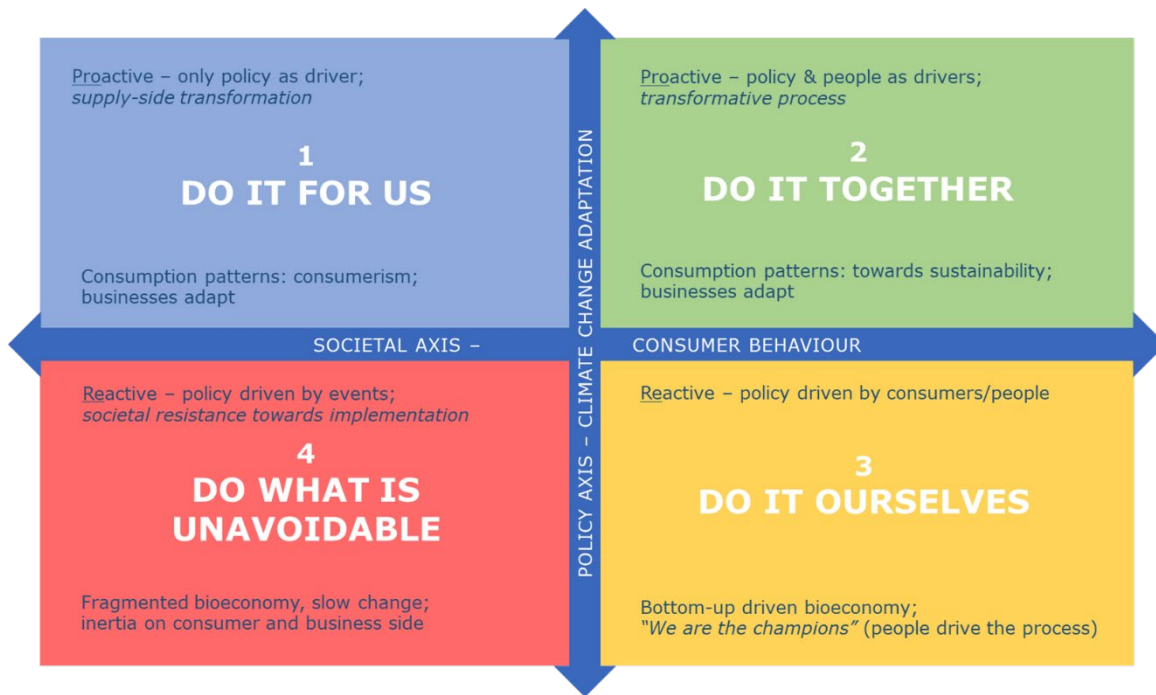


## 0.2 The scenario logic

In the 1<sup>st</sup> workshop, a scenario logic was identified, using a 2 x 2 matrix technique based on the most important and uncertain drivers, as identified by the workshop participants<sup>3</sup>.

Following the 1<sup>st</sup> workshop, the ad-hoc network of experts with input from EC has analysed the outcomes to define further the scenario axes and give them specific meaning and directions. This allowed obtaining a structured scenario logic (see Figure 1).

Figure 1 The scenario logic of the foresight process for the EU Bioeconomy



Source: Ad-hoc Network of Experts based on 1st Foresight Workshop outcome and EC proposal

The scenario matrix is built as follows:



**Vertical axis definition:** The capacity of the EU political system and its articulations to implement consistent, coherent, and effective policies that are directed towards the achievement of the climate-neutrality goal and the Sustainable Development Goals (SDGs), within the EU and contributing to achieving these goals outside.

In the upper part of this axis, this capacity is assumed to be high, with a proactive political system that anticipates and drives change.

In the lower part of the vertical axis, the capacity is assumed to be small, and the European political system is **reactive**, i.e. acting in reaction to popular calls from society, political events, or crises. Its agency is restricted by low acceptance of policies due to economic and societal inertia (and resistance).

<sup>3</sup> <https://ec.europa.eu/jrc/communities/en/community/cop-bioeconomy/article/future-transitions-bioeconomy-material-1st-foresight-workshop>

**Horizontal axis definition:** Society's attitude towards change, especially related to consumers' lifestyles, coherent with SDG 12 (Ensure sustainable consumption and production patterns). The left side of this axis assumes consumerism, i.e., the society is resistant to change, opposes "inconvenient" policies, aspiring instead to status quo, i.e., BAU societal motivations and consumption patterns. The right side of the horizontal scenario axis aims towards sustainability, i.e., society is pushing for change and willing to change consumption patterns and levels coherent with SDG 12, whilst calling for policy action.



The authors analysed the workshop results further and proposed a scenario outline, to which workshop participants added through an online survey in the 2<sup>nd</sup> half of August 2020 and in an online session on 1<sup>st</sup> September 2020. Based on that, the authors developed a draft scenario report using also knowledge about the long-term economic development, trade, energy, demography, etc. taken from projections on megatrends, such as Bisoffi (2019), Sitra (2020) and the EC Megatrends Hub<sup>4</sup>.

This draft was the basis for reviewing the scenarios for plausibility, consistency, and enrichment during the 2<sup>nd</sup> foresight workshop held on 17 – 18 Sep 2020<sup>5</sup>. The draft paper was extended based on recommendations from the 2<sup>nd</sup> workshop and finally presented and discussed in an online meeting on 20<sup>th</sup> October 2020<sup>6</sup>. This report is based on the extended draft, comments received, and further work of the authors.

### 0.3 The foresight scenarios for the EU bioeconomy

The combination of the two axes creates **four scenarios**:

- **Scenario 1 'Do it for us'**: A consistent and coherent set of policies is designed, and implemented to foster radical change in the supply systems, but society resists significant changes in demand (consumption) away from Business As Usual (BAU).
- **Scenario 2 'Do it together'**: Both the political system and society are aligned to achieve the climate-neutrality goal and the SDGs. Businesses quickly adapt and are part of the change. The transformative process includes all actors.
- **Scenario 3 'Do it ourselves'**: The political system shows an incapacity to implement significant climate and SDG policies. However, consumers change their attitudes and behaviour under the thrust of increasingly influential social movements and the aftermath of a series of dramatic crises. Subsequently, the resulting change of the demand (both patterns and levels<sup>7</sup>) drives the supply system to adapt.
- **Scenario 4 'Do what is unavoidable'**: Lifestyles do not change significantly from BAU patterns (but levels rise), and the political system is not able or supportive to implement/enforce proactive policies, limiting itself to adopt – with some delay – measures in reaction to crises.

The four scenario narratives **focus on Europe and its bioeconomy**.

However, geographical, economic, and geopolitical interdependencies are considered in the scenario assumptions or as aggregated global outcomes of scenario dynamics.

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<sup>4</sup> [https://knowledge4policy.ec.europa.eu/foresight\\_en](https://knowledge4policy.ec.europa.eu/foresight_en)

<sup>5</sup> <https://ec.europa.eu/jrc/communities/en/community/cop-bioeconomy/article/future-transitions-bioeconomy-material-2nd-foresight-workshop>

<sup>6</sup> <https://ec.europa.eu/jrc/communities/en/community/cop-bioeconomy/article/future-transitions-bioeconomy-%E2%80%93-report-back-foresight-workshops>

<sup>7</sup> Given the relatively small decline in EU population and its ageing until 2050 while overall income is assumed to rise, constant consumption patterns will result in rising consumption levels, e.g., more heated living space, fast turnover of appliances, clothing, furniture, and more travel.

## 0.4 Key drivers shaping the scenarios

The scenario narratives use the main drivers identified in the 1<sup>st</sup> foresight workshop and discussed further in the 2<sup>nd</sup> workshop, providing a comprehensive set of assumptions on [how the world might look like in 2050](#).

The assumptions reflect global data sources on economic development and productivity (WorldBank 2020, Dieppe 2020), energy (IEA 2020a+b), population dynamics (e.g., Abubakar 2020, Vollset et al. 2020), and trade (UN-ECLAC 2020). In brief introductions to each scenario narrative, respective drivers and trends are summarised to indicate which 'world' the scenarios represent. The following table provides a synopsis of the relevant drivers in all scenarios<sup>8</sup>.

*Table 1 Synopsis of relevant drivers of the foresight scenarios for the EU bioeconomy*

Drivers in the EU 2050	S1 'Do it for us'	S2 'Do it together'	S3 'Do it ourselves'	S4 'Do what is unavoidable'
<b>Ecosystem in the EU</b>				
- agroecology	↗	↗	→	↓
- bioeconomy-based carbon sequestration	↗	↑	→	↘
<b>Social system in the EU</b>				
- awareness and engagement for change	→	↑	↑	↘
- food security	→	↗	↗	↘
- food-related health concerns	→	↗	↗	↘
<b>Economic system in the EU</b>				
- bioeconomy-based employment	↗	↑	→	↘
- bioeconomy-based international trade	→	↘	↓	→
<b>Energy system in the EU</b>				
- bio-based electricity/CHP*	↘	↓	↘	↘
- bio-based heat	↘	↓	↘	→
- biofuels for transport	↗	→	→	→
<b>Material system in the EU</b>				
- bio-based chemicals, plastics etc.	↗	↑	→	→
- bio-based construction materials	↗	↑	↗	→
- bio-based fertilisers	↗	↑	→	→

Legend: ↑ strong increase ↗ increase → neutral ↘ decrease ↓ strong decrease

\* = bio-based electricity/Combined Heat & Power is shifted towards providing grid and system services (balancing)

Source: Estimates of the Network of Experts

<sup>8</sup> Note that the scenarios are affected also by drivers outside of the EU (not shown in the table but in the scenario narratives). A synopsis of key drivers and trends for the supply side of all scenarios is given in Table 3, and demand-side drivers, trends, and outcomes in Table 4 (both in Annex 1).



## 1 Scenario 1: Do it for us

Between 2020 and 2050 policymakers and business actors are strongly determined to introduce strict measures to keep global warming at 2 °C by 2100 (Paris Agreement). In a new global consensus, technological innovation, trade liberalisation subject to stringent environmental standards, business-friendly policies, and a more interventionist role of the State - through fiscal policies and regulation - are key drivers towards mitigation of and adaptation to global warming. Political and business elites consider the social costs of mitigation a necessary evil, so the social component of sustainability is not considered a priority. Consumption responds partly to higher prices of goods and services due to taxation and higher environmental standards, but the pressure of demand on resources remains high.

In Europe, the supply of primary agricultural production decreases by 25%. Simultaneously, consumption patterns follow the trend to decrease as already appeared in 2020, with a slight decrease in consumption of animal products and a shift to higher quality products. There is a general increase in prices, only part of which is compensated by a decrease in energy prices. As the demand for biomass feedstock increases, imports rise in parallel.

As the EU has taken leadership on sustainable transformation, the European food industry strengthens its position as a leader for ecological products. At the same time, it loses its position in the mass market. In 2050, social inequalities have increased, and more than 50% of the European population's real income is lower than in 2020. This brings to social discontent and political unrest. As a consequence of these developments, loss of biodiversity and social inequalities continue to grow.



## 1.1 The world and Europe in 2050

### Society

In the EU, the trend to depopulation and ageing has continued. Ageing has reduced the tax base and increased the average tax burden. The urbanisation and peri-urban development continued within Europe and globally, while depopulation of remote rural areas has accelerated.

Confidence in the EU green policies has convinced a growing share of EU citizens that green policies are worth higher prices, and they are willing to pay for higher quality.

However, they are not ready to radically change their eating, housing, and mobility habits, and levels of consumption remain more or less the same of 2020. The incidence of obesity and overweight does not improve concerning 2020 levels.

### Technology

Strong directionality of research policies has allowed a take-off of 'green' technologies, the cooperation between firms coordinating the flows of materials, and finally the development of management models that aims at circularity. Biotechnologies, in particular in the field of precision fermentation, have allowed the growth of a variety of novel food and non-food products.

Governmental policies also have stimulated innovative technologies in agriculture, bringing to a profound restructuring of farming and of the food system, with increasing concentration and supply chain integration.

*Transport* is primarily electrified (batteries, H<sub>2</sub>) except aviation, long-haul heavy-duty vehicles, and shipping where advanced biofuels are used.

The recycling of materials has increased enormously. In Europe, the recycling rate for plastics has reached 95%. Furthermore, plastic recovery from waste is improved by innovative technologies, significantly reducing the influence of household behaviour.

### Economy

After the COVID-19-related world recession, Member States have adopted interventionist approaches. Reduction of tensions between superpowers has strengthened multilateral trade rules, and a basic level of environmental standards has been introduced for most essential commodities. Consequently, the world economy started to grow again. Between 2030 and 2050, trade intensification and peaceful geopolitics have strengthened the role of [China and emerging countries](#) in the global economy<sup>9</sup>.

The generous post-COVID fiscal policies have stimulated [demand for goods and services](#), that has contributed to an increase of the general level of food prices. Although more home-office work reduces mobility related to commuting (Harper 2020), travel demand due to vacationing and business – reduced for some years after 2020 as a consequence of lifestyle changes after COVID-19 – resumes to pre-COVID-19 patterns (Gavira 2020, Mazareanu 2020).

Saving on energy costs due to efficiency gains and high shares of low-cost renewables allows families whose spending power has increased to buy higher-quality demand goods and services.

The business community, and especially large corporates, has strongly supported the policy-driven push to the sustainable transformation. The investments in 'green' R&I have increased by 20%. The financial system has promoted [sustainability standards](#) as criteria for evaluation. 'Sustainability-linked' bonds (Economist 2020a) – linked to environmental

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<sup>9</sup> In 2050, China will be the 1<sup>st</sup>, India will become 2<sup>nd</sup>, the US 3<sup>rd</sup>, Indonesia 4<sup>th</sup> and Brazil 5<sup>th</sup> largest economies, respectively. Germany will drop to the 9<sup>th</sup> place (as the first EU economy), and the EU share in global GDP will drop from 15% to 9% (all data from PWC 2017).

standards exceeding a minimum sustainability threshold - have achieved a 40% share on total investments.

By 2050, the EU food industry has strengthened its global competitiveness in the field of 'ethical' certified products and on high-quality food exports (wine, cheese, novel food).

However, given the growth of other market segments (cheap, mass-produced products), parts of the European food industry have lost positions vis-a-vis their global competitors. Chinese, Indian, and Brazilian corporations have emerged as the [new international food players](#).

The farming sector in Less Developed Countries is increasingly polarised between farms integrated into the global value chains and farms – mainly small-medium size - that produce for domestic 'spot' markets.

## **Environment**

The energy system transformation (decarbonisation) has progressed globally, with renewables dominating electricity generation and final energy consumption (IEA 2020c).

In 2030, agricultural GHG emissions have been reduced by about 55% compared to 1990 levels, and by 2050 climate neutrality has been achieved. Agricultural land has not expanded since 2020. Natural areas have increased by 40% of total land in 2050 compared to 2020. Forest productivity has remained broadly the same (balance between increased degradation in forest areas and efforts at remediation and enhancements to forest management).

Regulation has made it possible that forest harvest did not exceed growth rate but given the rising use of forest biomass for energy and bio-based materials (including wood for construction), forest carbon stocks are reduced over the period to 2050 compared to current levels, despite regulatory effort to manage carbon in forests. In consequence, forest carbon sequestration<sup>10</sup> is diminished compared to BAU levels.

Increased demand for food and other bio-based products, and the more stringent environmental standards that constrain productivity growth, have intensified the global [competition](#) for natural resources.

With trends in Europe and outside converging, [global warming](#) is mitigated so that by 2100, global temperature increase can be kept around 2 °C. Note that for consistency reasons, [all scenario narratives](#) consider that EU action towards climate change is matched by similar action [outside](#) of Europe, based on differentiated responsibilities.

## **Policy**

In this scenario, Policy is a key driver of change. In 2030, an updated and extended version of the European Green Deal was launched under the title [New Green Deal](#), with an expanded and extraordinary high investment plan (after Next Generation Europe) to keep Europe on track towards the target of carbon-neutrality by 2050 (see Box 1). As part of this, Member States collaborate in aligning national policies, especially on climate change mitigation and adaptation, and receive EU money for 'transformation funds'.

To achieve carbon neutrality by 2050, the Agriculture, Food, and Land Use sector (AFOLU) has been targeted to become carbon-neutral by 2035 (EC 2020b). The Vision for Rural Areas<sup>11</sup> has stressed the role of depopulated rural areas as providers of ecosystem services,

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<sup>10</sup> Forest carbon sequestration is defined here as net accumulation of carbon stocks in forests, minus losses of carbon stocks resulting from both natural disturbances and harvesting. This is equivalent to the carbon sink as defined above minus losses of carbon stocks from harvesting but allowing for carbon sequestration in wood products.

<sup>11</sup> To be released in 2021, see <https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12525-Long-term-vision-for-rural-areas>



prioritising the expansion and the management of protected areas and the growth of 'carbon farms' on marginal lands.

To align with the European Green Deal, the CAP has been reformed by 2025, its budget kept at 2020 levels, and objectives aligned with the SDGs (Matthews 2020). CAP National Strategic Plans have been approved timely and in coherence with the objectives. A robust and effective system of monitoring and performance assessment has been implemented. After 2030, the CAP is integrated into the Sustainable Bioeconomy Policy (see Box 1).

### **Box 1**      *The post-2030 "New Green Deal"*

Following the European Green Deal and the Next Generation Europe recovery package of 2020, the EU in the late 2020ies agreed on a **New Green Deal** to foster the transformation until 2050, with the following key components:

**Integration** of the CAP and the Regional Fund into a Sustainable Bioeconomy Policy (SBP), using an updated Taxonomy to consider (beyond climate change mitigation and adaptation) biodiversity improvements, and social cohesion. The SBP has €100 billion in the EU **annual** budget. Monetary support to farmers, fisheries and foresters focuses on agroecology and carbon farming as well as blue bioeconomy action and sustainable forestry.

**Replenishment** of the Just Transition Fund with about €100 billion, aiming specifically at payments for sustainable and circular bioeconomic rural development between 2030 and 2050.

**Extension** of the Circular Bioeconomy Fund to €100 billion for 2030 to 2050, leveraging private investments of some €500 billion in that period.

An increasing polarisation between urban elites and low-middle income people, often located in the peripheries and in semi-rural areas, has occurred. They have developed a strong resentment against politics and support populist anti-Europe sentiments.

The traditional nutrition transition from plant to animal proteins continued outside Europe. Growth of food prices due to higher environmental standards increased the number of 'food poor'. Growing food insecurity due to higher food prices has created tensions in Africa and Latin America, generating intensified immigration, and resulted in political turmoil and violent conflicts. Remote rural areas have continued to suffer depopulation and social desertification trends due to the increasing concentration of farming.

## **1.2 The EU bioeconomy in 2050**

### **Supply in the EU**

In 2030, the European Green Deal targets have been achieved in agriculture, fishing, and forestry. In 2050, the share of organic agriculture is 70% of the agricultural area; protected areas cover 40% of European land, the bioeconomy is carbon-neutral, pesticides and antibiotics are used only for emergency reasons. Due to climate change, reduction of agricultural land and adoption of less intensive farming methods, the volume of production decreased by 25% compared to 2020 levels.

#### *Food & feed crops, and livestock*

The area dedicated to food crops has decreased slightly, and the area devoted to feeding, mostly grass and alternative proteins to soy, has grown.

Thanks to the availability of renewable energies and of increasing food prices, **vertical farming** has grown, achieving a 25% share in fresh vegetables by 2050 (Pinstrup-Andersen 2018).

The total Livestock Units (LSU) have decreased by 30% in the EU, keeping the LSU/ha rate below 1 by 2030 (Buckwell & Nadeu 2018), and this trend continues until 2050. Meat production volume levels fall to 50% of the 2020 level and milk to 65% of the 2020 level. Livestock farms have enlarged their land base to adapt to the LSU/ha rate, and many small farms have disappeared.

Lab-food, especially meat imitations and cultured meat, has achieved a level of maturity by 2030 with a share in total food sales of 25% by 2050. Insects are grown mainly to provide feed for livestock (representing 10% of the consumption of proteins for feed by 2050). 'Electrofood' synthesised from CO<sub>2</sub> and renewable H<sub>2</sub> was introduced to the market

in 2034 and gained a share of 2% in the feed sector by 2050 (Monbiot 2018, Le Page 2020).

### *Forestry*

Total wood supply from EU forests increases within sustainable-yield limits by 10% by 2050 to meet the combined increased demand for wood for use in construction, other non-energy products (including, e.g., bioplastics), and bioenergy. Imports of wood also grow to meet the overall demand. Policies on carbon impacts only weakly constrain increased supply from forests because of push-back from the forestry, wood industry, and bioenergy sectors.

### *Blue bioeconomy resources*

The growth of aquaculture production, both offshore and inland, is limited by sustainability concerns and climate change (FAO 2018+2020). Despite these limitations, aquaculture has increased its production level by 25% until 2050. In particular, multitrophic aquaculture has developed sensibly. Strong EU regulation on fish capture led to a recovery of stocks after 2040. Algae production has doubled by 2050 (EC 2019b), helping Europe to reduce its deficit in this sector (EC 2020c). The microalgae production, which in terms of quantities is limited, has had a boost.

### *Non-food systems: bioenergy and biomaterials*

The bio-based industry grows by 20% until 2030 and by 50% until 2050, especially in bioplastics and fibres, sustained by an intense flow of imported (and certified) biomass.

Yet, there is some competition with food production, especially in areas where environmental and social conditions are more complicated, contributing to increased food prices.

Biomass demand for bio-based products (especially furniture, bioplastics, and fibres) has grown in parallel to wood for buildings. Bioenergy remains necessary for heat in rural areas and transport segments such as aviation, maritime and heavy-duty vehicles. Bioenergy has been strongly regulated, and advanced biofuels derived from domestic residues and wastes have been favoured. Conventional biofuels are phased-out by 2050.

An EU-wide incentive system shifts woody biomass used earlier for heating towards cascading use and biorefineries. Production of biomethane linked to animal farms has increased by 75% until 2050, and the market for digestate grows by 67% by 2050.

## **Demand in the EU**

The economic recovery post-COVID has stimulated the growth of demand. In 2050, consumers' behaviour is fragmented and polarised. Willingness to pay for high-quality products – including organic, pesticide and antibiotic-free, carbon-neutral - increases throughout Europe. However, a segment of 'heavy consumers' continues dominating the market. This segment, together with the 'food poor', grows with increasing shares of immigrant population.

Total consumption of animal proteins follows a BAU trend: until 2030, meat and fish consumption slightly increase in the EU (OECD & FAO 2020), consumption of cheese increases by 10%, milk decreases by 5% (EC 2019a). Trends are different between countries. The deficit of supply over demand brings to price increases, which in turn affect consumption patterns and limit demand growth. To fulfil domestic demand, imports grow, especially meat and fish, and exports, especially pork meat, decrease. By 2050, consumption of animal products falls to 2020 levels, and regional demand disparities level off.

## **Trade**

After a period of turbulence, extra-EU trade relations stabilise. In terms of trade flows, soy imports decrease, but demand for imports has increased significantly. In the meanwhile, the EU has managed to impose its sustainability standards and secured its access to 'sustainable' meat, palm oil, sugar. By 2050, these imports level off.

The GHG border adjustment tax favours domestic production. Imports of meat have reduced, but consumption and imports of fish has increased. Although Carbon tax has also raised consistently the prices of forest biomass, timber and wood biomass imports have increased with BAU trends in demand from consumers.

### **1.3 Outside Europe**

Dietary transition in developing countries has continued, creating a strong demand for animal proteins. Increased demand and pressure over land use have raised food prices, and in many developing countries, this has created food insecurity in urban areas and social inequalities. In Africa, food price increases worsened food insecurity, generating pressure to migrate.

To contribute to mitigating climate change, China has promoted strict consumption rules, with massive campaigns to reduce waste (Kuo 2020), to reduce meat consumption, and to adopt a 'Chinese diet,' low in animal proteins. Chinese rural policies have also promoted a reallocation of the population of remote rural areas into larger villages (Economist 2020b) and sustained large-scale carbon farms.

In the US and Latin America, increased levels of consumption and an increase in price levels have made the share of 'food poor' grow.

The difficulty and the costs of compliance with EU standards have generated a restructuring of farming and food business in less developed countries, increasing the dualism between integrated and non-integrated farms in the global value chains.



## 2 Scenario 2: Do it together

In Scenario 2, the European Green Deal goals and SDGs are achieved in 2030, i.e., the world is on track to keep projected temperature rise at 1.5 °C by 2100 - driven by proactive policy-making, civil society action, consumer choices, and response by business to innovate accordingly. The **transformation** of the bioeconomy towards circularity and sustainability (especially climate neutrality) progressed well, including the waste sector.

The political system uses effective instruments for climate change adaptation and mitigation and supports consumers in changing through coherent policy frameworks. In parallel, influential social movements help **radically changing** both supply and demand (patterns and levels). This scenario is in line with the '**BioWEconomy**' concept<sup>12</sup>.

In 2030, an updated and extended **New Green Deal**, with an expanded and extraordinary high investment plan was agreed to keep Europe on track towards carbon-neutrality by 2050. As part of this, Member States collaborate in aligning their national policies (especially regarding climate change mitigation and adaptation) and receive EU significant funding for transformation programmes.

The most relevant economic outcome of this scenario is the reduction in mass production and the increase of local, community-based high-quality production. The bioeconomy, including the food industry, offers innovative health and sustainability products. More spending on local food is possible due to savings in energy and transport expenditure. The urban-rural gap is shrinking.

<sup>12</sup> See Fritsche et al. (2020), especially Annex 3.



Governments and businesses cooperate with social movements, providing resilient supply and demand. Member States work collaboratively with EU institutions, amongst them and with non-EU partners. Businesses and civil society appreciate diversity, reducing intra-EU tensions of immigration.

Outside Europe, dietary changes, and sustainable food and energy system transformations happened, similar to within the EU, also in developing countries, strongly reducing demand for animal proteins and processed food. Land use is more efficient, and food prices only increase slightly, compensated by reductions in spending on energy and transport. Through partnerships, capacity building, and financial support, the EU fostered this change, including contributions from civil society and liaisons between producers and consumers in non-EU and EU countries.

Between the EU, Eastern Europe, and Russia, [sustainable trade](#) policy developed to a full transformation of the natural gas pipeline system into a biomethane and renewable H<sub>2</sub> trading bridge by 2050.

## 2.1 The world and Europe in 2050

### Society

In 2050, the world population reached 9.7 billion. Proactive European immigration policy reduced population decline so that in 2050, the EU population is only slightly less than in 2020. Urbanisation has stopped, and remote rural areas have become more populated again. Driven by proactive policymaking, civil society action, consumer choices, and response by business to innovate accordingly, the European Green Deal goals and SDGs are achieved in 2030.

The bioeconomy [transformation](#) towards circularity and sustainability (especially climate neutrality) progressed well, e.g., agroecology is the accepted practice of most farmers by 2050, forests are managed concerning biodiversity protection and carbon management.

In response to circularity as a dominant concept for businesses and policy, the waste sector is fully transformed.

The political system uses effective instruments for climate change adaptation and mitigation and supports consumers in changing through coherent policy frameworks.

In parallel, influential [social movements](#) help [radically changing](#) both supply and demand (patterns [and](#) levels). People – as citizens, consumers, members of civil society groups – are active in participating and shaping social life and transforming the (bio)economy. They are driving policies towards more integrative, long-term approaches, and increasingly organised on local (cultural and production) levels while maintaining links to the outside through very high-level digitisation.

This radical change resulted from massive ecological and political crises across Europe, which increased sensitivity to environmental issues, desires for dematerialised lifestyles, and social justice. Social movements, starting from community-level groups driven by young generations, encouraged the emergence of new production and consumption practices. Voluntary work, social enterprises, and cooperatives gained significantly moral authority in the society, and the administration levels have increasingly cooperated with them to address societal challenges.

With improvements in urban and rural living standards, the incidence of obesity and overweight is massively reduced. In the longer term, more spending on food is possible for most EU citizens due to savings in energy and transport expenditure, which pushes demand for local products. The gap between rural and urban areas is shrinking.

### Technology

The acceptance and adoption rates of new technologies increased, with strong convergence of digital, life science, and energy technologies, pushed by market pressure.

Transport is primarily electrified (batteries, H<sub>2</sub>) except aviation, long-haul heavy-duty vehicles, and shipping where advanced biofuels are used, in combination with rising shares of Power-to-Liquids ('electrofuels' from renewable H<sub>2</sub> and CO<sub>2</sub>).

Recycling of materials strongly increased, and Europe reaches a recycling rate for plastics of 95%.

## **Economy**

After the COVID-19-related world recession, world economies started to grow again but following a [different development logic](#). Reduction of tensions between the superpowers made it possible to strengthen multilateral trade rules, and strict sustainability standards have been introduced for most essential commodities.

Global food, housing, and mobility demands have grown, but at slower rates than 2020 due to changes in consumption in the Western World and China.

Businesses are increasingly (co-)owned and decentralised to adjust to transforming consumer and market demands. Businesses – supported by policies – are becoming drivers of the transformation, actively seeking to innovate and to improve their customer relations.

In 2030, an updated and extended [New Green Deal](#) (see Box 1), with an expanded investment fund, was agreed to keep Europe on track towards carbon-neutrality by 2050. As part of this, Member States collaborate in aligning their national policies (especially regarding climate change mitigation and adaptation) and draw from EU funds for transformation programmes:

Between 2030 and 2050, relatively high revenues from 'winner' industries allowed to partially compensate 'loser' industries (and their former employees) through concepts developed earlier, e.g., the Just Transition Funds of the EU and of Member States, which were partially filled with revenues from carbon taxes.

Due to aging and restructuring and transformation to agroecology and 'urban' farming, the number of farms decreased less than in the other scenarios.

New actors enter production, with positive effects on (rural) employment. Both larger-scale and small-medium multifunctional farms co-exist. Much land is re-naturalised or turned into carbon farms, supporting rural re-development.

The most relevant economic outcome of this scenario is the reduction in mass production and high rates of local, smart, community-based production with high quality. The bioeconomy – including the food industry - massively innovated health and sustainability products, becoming a global leader.

## **Environment**

Global competition for natural resources is low due to changes in demand for food and high-efficient and mostly circular bioeconomy production. The global energy system transformation succeeded, with renewables providing more than 2/3 of electricity and more than half of final energy consumption (IEA 2020c+d).

Successful mitigation of climate change by strong EU and international action achieves the Paris Agreements, i.e., the world is on track to keep projected temperature rise [at 1.5 °C](#) by 2100. The rising temperature until 2050 affected primary production due to increased pest diseases, intensification of droughts, and other extreme weather events. Still, effective adaptation policies reduced economic and societal impacts.

The rate of biodiversity degradation [decreased](#) significantly compared to 2020, due to the global implementation of agroecological and sustainable forest management practices. In parallel, much degraded land was restored, improving soil carbon and water availability.

By 2050, EU agricultural GHG emissions are reduced by ca. 80%. Agriculture achieves a drastic reduction in nutrient losses and harmful pesticide applications. Agriculture and forest land did not expand since 2020. Land-use change allows increasing [nature protection](#)



areas massively, including significant afforestation (where feasible) and trees in agricultural and urban settings.

Forest productivity is moderately enhanced (10%). Forest carbon stocks are only slightly reduced compared to current levels because of forest age-related factors. The EU does better than target for the LULUCF sector to contribute net removals in the period to 2050.

The ecological footprint of consumption in Europe decreased substantially, as also imports are subject to strict environmental and social standards and respective enforcement.

## Policy

The societal trends reshaped the political system by affecting political parties - first locally and then at the national and European level. Universities and research centres contributed consistently to this change by embedding sustainability into their strategic plans and encouraging a more vital interaction of researchers with society. Schools took up the 'BioWEconomy' theme as a practical approach for education, enhancing awareness of the close human-nature relation, fundamental to a sustainable society.

After the crises mentioned, political parties have undergone a profound renewal. The evidence that public spending was crucial in maintaining society's resilience vis-a-vis challenges such as the pandemic changed the previously dominant economic paradigm.

Responsibility in business and research, sustainable finance, and fair trade, under the EU leadership, has been mainstreamed internationally (transforming the WTO, forming the Agenda 2050), and most EU Member States are aligned in collaborative policies.

Policy development is dynamic and responsive: Governments and businesses cooperate with social movements, providing resilient supply and demand.

Member States collaborate with EU institutions, amongst each other, and with non-EU partners. Businesses and civil society appreciate diversity, reducing intra-EU tensions of immigration.

## 2.2 The EU bioeconomy in 2050

### Supply in the EU

#### *Food & feed crops, and livestock*

In 2050, agricultural production is, on average, 35% less than in 2020 due to agroecology, less animal protein production, and converting arable and grassland back to nature. Climate change impacts are mediated through innovation and less intensive farming methods. The average size of farms turns back to 2020 levels, and the crop diversity index increases.

The EU-average GHG emission factor for animals decreased by approx. 25% and the total Livestock Units (LSU) by 50%. Meat and dairy production levels fell to ca. 65% of the 2020 levels. Animal farm production of biomethane rises to about 75%. In parallel, the market for digestates becomes dominant by 2050, as demand is reduced by agroecology.

#### *Forestry*

Total wood supply from EU forests increases within sustainable-yield limits by 2050 to meet the combined increased demand for wood used in construction, for other non-energy products (including, e.g., bioplastics), and bioenergy.

Within the EU, forest management practices evolved towards the principles of 'climate-smart forestry', including both mobilising available wood resources and ensuring long-term conservation of forest carbon stocks and carbon sequestration.

EU imports of wood increase to meet overall demand. However, the level of supply is constrained to ensure that negative impacts on GHG emissions in the LULUCF sector are avoided due to a strong forest carbon accounting applied even outside of the EU.

### *Blue bioeconomy resources*

Between 2020 and 2025, fish captures maintained at high levels due to demand, with inevitable pressure on stocks and marine biodiversity. After that, a strong EU regulation on fish capture led to a recovery of stocks after 2040. Fishery capacities were adjusted by generous EU funding (as part of the New Green Deal, see Box 1), favouring the transformation of many smaller-scale fisheries to aquaculture and macro-algae production, with societal pressure from community-based action groups supporting this dynamic.

The growth of aquaculture production, both offshore and inland, is limited by sustainability concerns and climate change (FAO 2018+2020). Despite these limitations, aquaculture increased by 15% until 2030 and by 25% until 2050, compared to 2020.

Policies to drive innovation helped that, despite environmental standards on sustainable yields, algae production doubled by 2050, reducing Europe's protein deficit (EC 2020c). Microalgae production had a boost, but given the relatively low level of production, algae production in 2050 is still a niche in the European bioeconomy.

### *Non-food systems: bioenergy and biomaterials*

Between 2020 and 2050, biomass demand for bio-based products (especially bioplastics and fibres) increased significantly, but residues and wastes provide the primary feedstocks due to successful recycling and efficiency gains in production.

Large parts of **grassland** that were 'freed' by less animal protein demand are used for decentral grass biorefineries co-producing proteins.

The bio-based industry grows by about 50% until 2050, especially in bioplastics and fibres, driven by consumer demands and high innovation rates for new products.

Advanced biofuels are mostly derived from domestic residues, biowastes, and crops on degraded land; conventional biofuels (including imports) are phased-out by 2050. Direct solid biomass use for energy is decreased and shifted to biomaterials but remains part of cascading use, improving circularity of the bioeconomy.

Biomethane for industrial processes and high-temperature heat increases, while for electricity, biomass provides mainly system services<sup>13</sup>. The direct utilisation of forest biomass increases, but moderately, and strongly regulated by considering carbon impacts.

### **Demand in the EU**

In 2050 consumers have a high preference for local, low dairy food, and avoid food wastes (see also Scenario 3). Consumers are interested in long-living (biobased) products and increasingly recycle. Businesses adapt accordingly, offering innovative products.

This transformation is supported by policies (e.g., financial incentives for innovation, investment grants for forerunners) which also reward **socioeconomic** innovations and foster demand-side changes.

**Consumer patterns** change driven by preferences for locally produced food and materials. The total consumption of animal protein decreases in the EU. Increases in wood supply (EU and imported) are constrained by demand-side pressure for certified products, including criteria covering climate impacts, according to standards set by NGOs and civil society.

Travel demand due to business trips and vacationing is reduced for some years after 2020 due to COVID-19 and stays well below BAU, with more telework reducing commuting. People change travel modes towards walking, bicycling, and public transport in urban areas, with respective infrastructures being improved accordingly. Intra-EU aviation is

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<sup>13</sup> This term means that bioenergy (mainly biomethane) is used to provide flexible capacity to balance other renewable generation, especially variable power from wind and solar, both regarding overall generation, and frequency control.

shifted to high-speed trains, and demand for cars is massively shifted towards car-sharing, especially with electric drives in cities.

Social acceptance of the sharing economy is high, and innovative marketing and 'social entrepreneurship' are accepted business modes, blurring the divide between producers and consumers.

## **Trade**

After a period of turbulence, trade patterns have changed dramatically. Europe is leading to high-quality food exports (cheese, novel food, wine) and innovative biobased products. Domestic industry and farmers are 'protected' by a [carbon border tax](#) from non-EU competitors, and imports change from feedstock to high-quality products subject to sustainability standards, following fair trade principles.

Instead of fossil fuel, the EU imports renewable gases from Russia, the Middle East, and Africa, fostering transformation in the exporting countries.

## **2.3 Outside Europe**

Outside Europe, dietary changes, and sustainable food and energy system transformations happened similar to the EU, also in developing countries, strongly reducing demands for animal proteins and processed food.

Land use is more efficient, and food prices only increase slightly, compensated by reductions in spending on energy and transport.

Both urban and rural food security is improved, and social inequalities are lessened. Through partnerships, capacity building, and financial support, the EU has fostered this change, including substantial contributions from civil society and new liaisons between producers and consumers in non-EU and EU countries.

Africa and Latin America trade sustainably agricultural commodities with Europe at significantly lower physical levels, but with a higher value per tonne.

The partnerships between local producers in these regions and consumer groups in the EU are developing well, supported by the use of digital systems which improve transparency and reduce transaction cost.

Partnerships also develop between African and Latin American local producers of sustainable bioenergy (for biofuels).

Northern Africa and the Middle East have pioneered in transforming their fossil-fuel based economies into global renewable energy providers, and the EU imports some of that.

Between the EU and Eastern European countries, and Russia, sustainable trade policy was established in the 2030ies and has developed to a full transformation of the natural gas pipeline system into a [renewable gas](#) (biomethane and some renewable Power-to-Gas and H<sub>2</sub>) trading bridge by 2050.

The supply of biomethane supports agroecology in the exporting countries, whereas the revenue derived from the renewable gas trade is lower (but more stable) than previously.

Asia, North America, and Oceania import high-quality products from the EU, especially biobased products, and 'luxury' food items.





### 3 Scenario 3: Do it ourselves

Scenario 3 represents a strong **societal movement** towards actively pursuing a more sustainable and circular bioeconomy despite **weak policy** development and slow rate of policy implementation in Member States. Global temperature increase is **kept at 2.5 °C** by 2100, missing the Paris Agreement target.

Under the thrust of increasingly influential social movements, and in the aftermath of a series of dramatic crises, people radically change attitudes and behaviour, and the resulting change of demand (patterns **and** levels) drives the supply system to adapt. Young activists and minority groups (race, age, income, etc.) communicate and educate through social media and activist campaigns.

The European Green Deal goals have not been achieved and the funding schemes have not been implemented effectively because Member States did not respond efficiently to EU policy with appropriate measures in place.

The most relevant economic outcome of this scenario is the increased rates of local, smart, community-based production with high quality. The bioeconomy – including the food industry – slightly increases innovation for health and sustainability products, based on own funds, but parts of the traditional 'mass production' industry remain.

Governments are **incapable** to implement effective policies for sustainability. The business community strongly supports the push to the ecological transition, but there is a lack of public incentives/funding. Local businesses & SMEs have an advantage over large corporations.

Outside Europe, the dietary transition in developing countries towards demand for animal proteins and processed food has slowed down but increased overall demand and pressure over land use has raised food prices. This increased food insecurity in urban areas and social inequalities in many developing countries. Demand-side processes like in Europe also occur outside, especially in China, Canada, Pacific, and, to a lesser extent, in the USA.

### 3.1 The world and Europe in 2050

#### Society

Slight improvements in living standards in urban and rural areas. The incidence of obesity and overweight has reduced 50% from levels of 2020. In the longer term, more spending on food is possible for many more EU citizens due to savings in energy expenditure so that by 2050, this pushes the demand for local products.

The gap between rural areas and urban areas has become smaller.

#### Technology

The adoption rate of new technologies has increased, with a strong convergence of digital, life science, and energy technologies, pushed by market pressure. The rate of acceptance of new technologies has increased through all-inclusive methods in teaching and communicating and co-designing solutions with communities, schools, etc. to gain interest, understand and contribute.

#### Economy

Due to aging and restructuring, in 2050, the number of farmers has decreased from 10 to 6 million, while small-medium farms integrated into short food supply chains have increased. The tendency to polarize between large-scale, often vertically integrated, farms and small-medium multifunctional farms has continued. Many remote areas are re-naturalised or turned into carbon farms/non-food crop farms.

The most relevant economic outcome of this scenario by 2050 is the reduction in mass production, but the growth of production does not catch up with the pace of growing demand. This is due to low rates of local, smart, community-based production with high quality primarily because of limited access to finance for small scale local businesses and conservative attitudes of farmers.

The European food industry, however, has continued to innovate on health and sustainability products, becoming a [global leader](#) in this segment. Sustainable eco-tourism grows, stimulated by respective demands from citizens.

#### Environment

In Scenario 3, global warming is mitigated so that global temperature increase can be [kept at 2.5 °C](#) by 2100. Climate change has strongly affected primary production due to the increase of pest diseases, intensification of droughts, and other extreme weather events. Due to the drastic response of consumers/people, however, the rates of both biodiversity degradation and of species extinction have decreased.

#### Policy

Policy development is slow, and there are tensions between governments and social movements that wish for more robust supply and demand policies. Some Member States start to back these movements and ask for an increase in environmental standards.

### 3.2 The EU bioeconomy in 2050

#### Supply in the EU

*Food & feed crops, and livestock*

Due to climate change, to the reduction of agricultural area and the adoption of less intensive farming methods, in 2050, the level of food production decreases by 25%. The

average size of farms and the crop diversity index of farming have increased. A growing part of agricultural land is transformed into mixed farming by implementing carbon farming practices such as agroforestry, crop rotation, etc.

The area dedicated to food crops decreases slightly, and land for feed (mostly grass and alternative proteins to soy) grows. Thanks to availability of renewable energies and increasing food prices, vertical farming has grown, achieving a 5% share in fresh vegetables by 2030 (Pinstrup-Andersen 2018). By 2050 this share has grown to 25%.

Self-sufficiency through 'grow-your-own' patterns increases where feasible. Dietary changes triggered by responsible consumption provide opportunities to revive local varieties as well as alternative species for fisheries and aquaculture. Native tree species are sustainably managed for conservation and forest products due to increased societal awareness.

Meat and dairy production by 2050 fell to 80% of 2020 levels and shifted to higher quality products, but emission factors are not reduced enough. Production of biomethane linked to animal farms increased to 75% until 2050. The market for digestate grows to 67% of the total fertiliser market by 2050. Domestic biomass supply improved by efficiency and better practices.

The structure of livestock farms consists mostly of middle-to-large sized, integrated animal/crops farming (Ryschawy et al. 2017), grass-feed/agroforestry, closed-cycle animal farms, and small-middle size livestock intensive farms. Large-sized precision intensive livestock is kept at 2020 levels due to the lack of policy implementation and incentives.

#### *Forestry*

Total wood supply from EU forests increases within sustainable-yield limits by 2050 to meet the combined increased demand for wood for use construction, other non-energy products (e.g., bioplastics), and bioenergy.

Imports of wood also increase to meet the overall demand. Policies on carbon impacts only weakly constrain increased supply from forests because of push-back from the forestry, wood products, and bioenergy sectors, but demand-side factors mitigate these pressures.

#### *Blue bioeconomy resources*

The growth of aquaculture production, both offshore and inland, is limited by sustainability concerns and climate change (FAO 2018+2020). Despite these limitations, aquaculture has increased by 15% until 2030 and by 25% of 2020 levels until 2050, while fish derived mostly from wild captures could be limited to sustainable fisheries practices (e.g., MSC labelled).

Algae production has doubled (EC 2019b), helping Europe to reduce its deficit in this sector, but given the relatively low level of production (0.2 million tons over 33 million tons produced worldwide), algae production in 2050 is still a niche in the European bioeconomy.

#### *Non-food systems: bioenergy and biomaterials*

Between 2020 and 2050, biomass demand for bio-based products (significantly bioplastics and fibres), bioenergy (in domestic & tertiary small/medium scale heat in rural areas), as well as advanced biofuels for aviation and marine increased. Domestic supply barely matches due to the lack of policy support. This increases demand for sustainable imports, which follow several certification schemes. There is some competition with food production, especially in areas where environmental and social conditions are more complicated. Biomethane use increases for high-temperature industrial heat and smaller-scale cogeneration/cooling.

Advanced biofuels (mostly imported) are derived from residues, biowastes, and crops on degraded land; conventional biofuels are phased-out by 2050. Solid biomass is used increasingly due to residential demand, little biomethane for industrial processes, and heat, while for electricity, biomass use is only for system services, especially grid balancing.



## **Demand in the EU**

In 2050 consumers have a high preference for local low dairy food and avoid food wastes. The group of LOHAS (Lifestyles of Health and Sustainability) has increased, 'heavy consumers' decreased due to consumer awareness and choices. Consumers are also interested in long-living (biobased) products, and increasingly recycle. Businesses adapt their production accordingly. There is, however, slow development and implementation of appropriate policies.

**Consumer patterns** change, driven by preferences for locally produced food and materials. The total consumption of animal protein decreases in the EU. Mobility for business trips and vacations is reduced for some years after 2020 because of COVID-19, and stays below BAU, with more telework reducing commuting.

People change their travel modes towards responsible eco (sustainable)-tourism, walking, bicycling, and to public transport in urban areas albeit restricted by infrastructures. Air travel is reduced somewhat due to available high-speed train connections, and demand for cars is massively shifted towards car-sharing, especially with electric drives in cities.

New and sustainable technologies (artificial meat, plant-based proteins) are accepted if they are fit for purpose and appropriately priced.

## **Trade**

After a period of turbulence, extra-EU trade relations stabilise by 2030. Europe has strengthened its specialisation on high-quality food exports (wine, cheese, novel food) and other commodities (e.g., animal products, etc.). Markets are fragmented, and decentra-  
lised production is growing. All imports are reduced by 50% from 2020 levels.

## **3.3 Outside Europe**

The dietary transition in developing countries towards the demand for animal proteins and processed food has slowed down but increased overall demand and pressure over land use has raised food prices, and in many developing countries, this increased food insecurity in urban areas and social inequalities.

The difficulty and costs of compliance with EU standards created a financial crisis in the sector in Less Developed exporting countries. The transition has generated a dualism between certified systems and uncertified systems, the ecological footprint of which has increased.

Demand-side processes like in Europe also occur outside, especially in China, Canada, Oceania, and, to a lesser extent, in the USA.

Smaller-scale enterprises grow, local businesses, and direct consumer distribution channels gain advantages. Self-sufficiency patterns (e.g., grow your own, do-it-yourself, etc.) increase, and 'peer to peer' networks gain trust.

Driven by growing demand, agroecology achieves a share of about 1/3 of agricultural land by 2050. Natural areas are below 25% of total land.



## 4 Scenario 4: Do what is unavoidable

This scenario considers the case where policymakers and society **fail** to proactively adopt measures to fight climate change and global warming, with GHG emissions on a path towards a **3.5 °C** temperature increase by 2100. Measures are taken only when they cannot be avoided. The European Green Deal goals and the SDGs are **missed**, mainly due to the BAU behaviour of consumers and consequent consumption patterns: the slow rate of change leaves sufficient time for society to adapt. Weak policy support is given to innovation; conventional fuels dominate with a small share of biofuels and electrofuels.

In the EU, soil degradation and loss of biodiversity progress, which cause further reduction of food production (25% less in 2050 compared to 2020, with the agroecology model at 30% of total land, and natural areas below 25%) and competition for resources, with increasing biodiversity losses. This, in turn, favours strong market price fluctuation.

The EU CAP fails in meeting climate goals and supporting farmers in a green transition. This increased pressure in a fragmented and polarised farm market environment also causes more difficult access to healthy food. In 2050, farms are increasingly divided in size, while extreme weather events occur more frequently, and agricultural and forestry production drops, with reduced LULUCF sequestration by 2050.

At the societal level, some environmental movements emerge and react to these circumstances, but their fragmentation and a significant opposition reduce their impact on policy and society. The prevailing short-term vision generates winners and losers in society.

On a global scale, further tensions in food prices and local communities exist in Less Developed Countries due to increased droughts and food insecurities, with growing inequalities favouring more migration.

## 4.1 The world and Europe in 2050

### Society

In 2050, the world population reached 9.7 billion. The demographic development in the EU follows the BAU patterns: the EU population tends to decrease and to get older, and immigration policies hinder balancing population loss. In Europe, the urbanisation trend slowed down due to the lower quality of life in cities. On the other hand, in remote rural areas, the depopulation trend accelerated.

Towards 2050, after more stringent nutrition policies, the incidence of obesity and overweight returned to 2020 levels. However, lifestyles become less healthy due to the increased costs of living. The growing concentration of the farming sector, the soil degradation, and the conditions created by climate change enlarged the gap between rural and urban areas.

### Technology

The adoption rate of new technologies progressed, with a strong convergence of digital, life science, and energy technologies, pushed by market pressure. The rate of acceptance of new technologies has increased: however, public support and stimulus to innovation decreased due to weak stimulating policy measures.

### Economy

After the COVID-19-related world recession, world's economies started to grow again. The reduction of tensions between the superpowers after the elections in the USA made it possible to strengthen multilateral trade rules, and a basic level of sustainability standards have been introduced for the essential commodities.

Between 2030 and 2050, trade intensification and pacific geopolitical relations have strengthened the role of China and emerging countries in the global economy (in 2050, India, Indonesia, and Brazil, are the second, the fourth, and the fifth-largest economies, respectively). India surpassed China as the most populated nation. Population growth has intensified the demand for food and raw materials, creating intense pressures on food prices.

World trends in consumption, especially in mobility, housing, and food, have not changed significantly. The nutrition transition (from plant-based to animal proteins) continues, and demand for energy and materials grows.

Due to ageing and agricultural restructuring, the number of farms in 2050 decreased from 10 to 5 million. Polarisation between large-scale farms, often vertically integrated, and small-medium multifunctional farms intensified. Many remote areas are also turned into non-food crop farms.

The most relevant economic outcome of this scenario by 2050 is farming into global value chains. Concentration in the farming sector and specialization allows economies of scale, especially in the livestock and the cereal sector, but the industry and retailers mainly capture the efficiency gains.

Pushed by a growing demand, a segment of the European food industry has continued to innovate on health and sustainability products, but a segment of mass-produced food is still vital. Agricultural prices tend to maintain the level of 2020.

### Environment

Worldwide competition for natural resources grew due to increased demand for food and bio-based products. The energy system transformation (decarbonisation) progressed not much: at the global level, renewables supply about 50% of electricity and about 30% of final energy. Given the high energy demand, the prices of fossil fuels have kept levels similar to 2020.

Until 2050, agricultural GHG emissions have reduced by 35%. Agriculture achieves 50% fewer nutrient losses and harmful pesticide applications. The degradation of biodiversity



has continued. The soil loss rate has continued as before. Many regions experience warming above global average levels. Catastrophic climate events intensified, creating heavy losses in agriculture: the overall vulnerability of the environment increased and associated risks.

The dependency link among food, energy, and water has further developed, with increasing energy consumption to desalinate and supply fresh water to communities heavily affected by climate change effects. There are minimal efforts towards woodland expansion, planting of trees outside of forests, including in urban areas.

Forest productivity drops below current potential because of increased damage and degradation and only limited efforts at remediation. Forest carbon stocks are reduced compared to BAU levels. Forest carbon sequestration is reduced compared to BAU levels. The EU significantly fails to meet policy targets for mitigating or reducing GHG emissions because of reduced sequestration in the LULUCF sector in the period to 2050 combined with insufficient reductions in other sectors. However, the "overshoot" may be hidden wholly or partially because of weakened forestry accounting rules.

Transport has been electrified in urban centres (batteries, H<sub>2</sub>). However, combustion engines with fossil and bio-based fuels dominate, especially in aviation, for long-haul heavy-duty vehicles, and in shipping. Electrofuels play a minor role due to missing policy incentives.

Recycling of materials has increased in 2050, and especially in Europe, the recycling rate for plastics is above 30%.

The global temperature increase is projected to reach 3.5 °C by 2100 as global warming is partially mitigated. Climate change strongly affected primary production due to the increase of pest diseases, intensification of droughts and other extreme weather events.

The rate of biodiversity degradation has increased, and the extinction rate of species increased dramatically.

## **Policy**

The worsening of environmental and food-related health conditions created discontent in society and the rise of a strong but fragmented environmentalist movement, underrepresented in the political system. Member States accuse each other of not acting enough for the environment.

Political fragmentation has not been overcome, and a growing anger mounts against farmers, identified as the main responsible for environmental degradation. In the absence of agreement over the reform of agricultural and food policies, the budget allocated to them is radically reduced.

The impacts on the environment, agriculture, economy, business, and society will generate societal movements reacting to such an adverse scenario.

However, actual effects will depend on the status of social fragmentation, increasing uncertainties and short-term visions, and causing winners and losers in society and thus different reactions.

All these elements will impact on the policymaking process, eventually forcing policymakers to act or - more often - not.

## **4.2 The EU bioeconomy in 2050**

### **Supply in the EU**

#### *Food & feed crops, and livestock*

Climate change will accelerate soil degradation, leading to loss of agricultural area and land abandonment. Subsequently, the 2050 production is 25% below 2020 levels.

For some food products, this implied periodical surpluses and consequent market crises with increased and fluctuating prices. Malnutrition in society will tend to increase.

The CAP fails to adequately support farming and climate change adaptation, resulting in missing the climate goals. In 2050, meat and milk production remain on 2020 levels. The resulting surplus has created repeated market crises and strengthened export.

#### *Forestry*

Total wood supply from EU forests increases within sustainable-yield limits by 2050 to meet the combined increased demand for wood for use construction, other non-energy products, and bioenergy. Imports of wood also increase to meet the overall demand. Trends are driven by economics, with minimal consideration of climate change goals.

Policies on carbon impacts very weakly constrain increased supply from forests because of push-back from forestry, wood industry, and bioenergy sectors, including demands to relax forestry and bioenergy accounting rules.

#### *Blue bioeconomy resources*

Aquaculture production increased by 25% until 2050, while fish captures are maintained at 2020 levels. EU policy is unable to agree on reducing pressure on overfished stocks.

#### *Non-food systems: bioenergy and biomaterials*

Biomass supply for bio-based products (especially bioplastics and fibres) increased by 50% in 2050 due to increased demand. Due to the fragmented policies in the EU, advanced biofuels are derived from both domestic residues and wastes and imports (continuation of current policies).

Solid biomass is used to some extent due to residential demand, and some biomethane for industrial processes and heat, while for electricity, biomass use is only for system services. Utilisation of forests as a biomass source remains weakly regulated in terms of carbon impacts.

### **Demand in the EU**

Trends tend to reduce the levels of food consumption. The demand for animal proteins has not decreased significantly. Some consumers continued following the trend to LOHAS (reduced quantity and more quality) but find it increasingly difficult to get products that meet their expectations.

Timber and woody biomass imports increase, with BAU trends in demand from consumers and push-back from forestry and wood/biomass sectors against carbon regulation.

After 2020, business travel and vacation are reduced for some years following COVID-19 pandemic, but after that resume to pre-pandemic patterns with rebound effects. More telework reduces commuting, but overall transport demand increases significantly by 2050.

Due to underinvestment in public transport infrastructure, mode shifts of consumers remain low, and private car use and trucks for freight continue their dominance.

### **Trade**

In 2050, Europe has strengthened its position in the international agricultural and food trade, and also for some other biobased products. Fish, feed, biomass feedstock imports have increased.

## **4.3 Outside Europe**

The dietary transition in developing countries has continued, creating a strong demand for animal proteins and processed food. Increased demand has generated pressure over land use. Droughts have been intensified. Food prices have grown, and market crises increased.

In many developing countries, food insecurity has grown, generating strong migration flows. Exports from the EU and the US limited the competitiveness of the food sector of many Less Developed Countries (LDC).

Driven by rising demand for bio-based products, large land investments in LDCs were made, creating further tensions on food prices and local communities.

## 5 Foresight scenarios results overview

Following these drivers and the scenario narratives, the authors estimated to what extent the scenarios would contribute to the European Bioeconomy Strategy objectives, and selected SDGs. The respective results are shown in the following table<sup>14</sup>.

Table 2 Synopsis of results of the foresight scenarios for the EU bioeconomy

Bioeconomy objectives (EU scope)	S1 'Do it for us'	S2 'Do it together'	S3 'Do it ourselves'	S4 'Do what is unavoidable'
Mitigate/adapt to climate change	+	++	+	--
Reduce non-renewable, unsustainable resources	0	++	+	0
Manage natural resources sustainably	0	+	0	-
Strengthen EU competitiveness, create jobs	+	++	-	-
Reduce inequality	-	+	+	-
Improve food security	0	++	+	-
Improve health	0	++	++	-
Improve resilience	0	++	+	--

**Legend:** ++ very positive + positive 0 neutral - negative -- very negative

Source: Estimates of the Network of Experts

The table indicates the relative strength of the scenarios in achieving the European Bioeconomy Strategy objectives (lines 1 to 6), as well as SDG 3 (health), and resilience (as a COVID-19 response strategy).

The most positive impacts on the objectives are shown by the '++' indicator, while the most negative impacts are indicated by '--'.

Scenario 1 achieves the EU climate target and improves domestic employment, while not contributing much to the other objectives, and fails on reducing inequalities.

Scenario 3 does not fully achieve the EU climate target but performs better than Scenario 1 on the other objectives, except for domestic employment.

Scenario 4 achieves **none** of the Green Deal targets and misses the climate target. This reactive 'muddle-through' scenario clearly is the **least** preferred development for the EU bioeconomy.

Scenario 2 (which is a **combination** of Scenarios 1 and 3) gives the **best overall results** and avoids negative trade-offs. With regards to the SDGs, Scenario 2 allows to meet those related to the bioeconomy by 2030.

<sup>14</sup> Note that the scenarios also imply possible impacts outside of the EU (positive, neutral, negative), but this is not considered in the table (but in the scenario narratives).



## 6 Initial reflections on transition pathways

A key discussion point during the 2<sup>nd</sup> foresight workshop was the question: [How do we get to the explored set of scenarios, especially towards the 'best' scenario?](#)

In the following, some reflections on the possible transition pathways of the EU bioeconomy towards 2050 are given, with a focus on potential 2030 milestones.

For Scenarios 1 and 2, a key milestone will be the [New Green Deal](#) (see Box 1) with an expanded and extraordinary high investment plan (after Next Generation Europe) to keep the EU on track towards the target of carbon-neutrality by 2050.

Another milestone for Scenarios 1 and 2 is updating and [strengthening the ambition of the next CAP reform](#) to pave the way for the agroecological transformation, as part of starting the food system transformation. After 2030, the more prominent sustainability orientation of the fishery policies must be achieved, integrated with extending the [blue](#) bioeconomy and transformation support for coastal villages and regions from the [New Green Deal](#).

A third key milestone for Scenarios 1 and 2 is to engage in bi- and multilateral [trade policies](#) to introduce agreed sustainability standards at least for bioeconomy-related commodities (agricultural, fishery and forestry products), and implement [border adjustments](#) for the EU carbon tax to level the playing field for the EU economy and its trade partners.

Two more milestones concern Scenarios 1 and 2:

- The massive extension and transformation of [infrastructure](#) (trans-European transport networks for high-speed trains and freight as well as electricity systems; opening gas pipeline transmission and distribution to renewable gases)
- Adjusting the rural development funding (Regional Funds etc.) with the next CAP reform to foster agroecology, carbon farming, and smaller-scale biorefineries.

Both milestones could draw from the funds available until 2030, and the [New Green Deal](#) afterwards.

Finally, Scenarios 1 and 2 require to fully implement sustainable circular bioeconomy investments into the [EU Taxonomy](#)<sup>15</sup> and continue to adjust the Taxonomy with regard to 'crowd funding' schemes, especially for Scenario 2.

For Scenarios 2 and 3, the [strengthening of the cultural and social activities](#) is fundamental to foster the demand-side transformation, especially in food and transport systems. In Scenario 3, this will be a bottom-up dynamic, as EU (and Member States) policies remain reactive.

In Scenario 2, this must be achieved through pro-active EU policy concerning consumers (better and clear [labelling](#) of sustainable products<sup>16</sup>, taxes for non-renewable products and quota systems) well before 2030 to allow for consumers' behaviour adaptation. Furthermore, inclusive EU policies towards communication and education on the '[BioWEconomy](#)' (Fritsche et al. 2020) are crucial and should [partner](#) with actors from [culture and arts](#) to reach out more effectively to the EU citizens. To prepare for this, a key milestone might be a series of media campaigns and (online) EU 'townhall meetings' with respective actor groups in the next years.

Scenario 2 also [requires policy integration](#) both horizontally (across sectors), and vertically (EU, Member States, cities and regions, citizens). This key challenge and respective policy options are described more fully elsewhere (Fritsche et al. 2020).

For Scenario 4, there are no milestones, as this scenario represents reactive policies and inertia on the business and citizen side. This 'muddle through' is an extension of the BAU policies of the last 30 years, and – in the [absence of transformation dynamics](#) – may well describe the future ahead.

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<sup>15</sup> [https://ec.europa.eu/commission/presscorner/detail/en/ac\\_20\\_1916](https://ec.europa.eu/commission/presscorner/detail/en/ac_20_1916)

<sup>16</sup> Part of this would be to continue Green Deal activities such as the "renovation wave" which aims to modernise European building stocks (EC 2020d). Here, quota for bio-based construction and thermal insulation products could be effective.

## 7 Key insights for the future of the bioeconomy

This final section summarises key insights gained from exploring the foresight scenarios for the EU bioeconomy.

- In **Scenario 1 'Do it for us'**, the policy focus is on the **supply side** only. This is effective for **climate change** adaptation and mitigation but creates **strong trade-offs**. The missing demand-side transformation requires more extensive (and expensive) supply-side measures than in Scenario 2 and implies risks for social acceptance.  
A post-2030 '**New Green Deal**' is crucial to foster innovation, and (some) collaboration with Member States. The **social** side of sustainability, and outside of EU impacts, are problematic, though.
- **Scenario 2 'Do it together'** follows an **integrative approach** and delivers best but is also **most challenging**. Bioeconomy policy must reach out to society, be inclusive towards Member States (**diversity**), and social movements. The post-2030 '**New Green Deal**' (with expanded funding) is required, but political system/parties need change as well. The bioeconomy is built from the ground (bottom-up) and collaborative top-down (clusters and networking), also with **partners outside** of the EU.
- **Scenario 3 'Do it ourselves'** has a focus on the **demand side** which opens opportunities but restricts effectiveness for **climate change** adaptation and mitigation by missing policy support and lagging transformation of businesses (incentives only for innovators and 'winners'). Strong **socio-cultural movements** are fundamental ('all week for future'), based on local action & networking. Awareness-raising and education are **not only** a matter for (Member) States, but part of broad **socio-cultural** activities.
- **Scenario 4 'Do what is unavoidable'** is the most unfavourable, but may well be the most realistic, given the trends over the last three decades. A 'muddle-through' logic of short-sighted, uncoordinated and non-integrated policies along levels (global, EU, Member States) as well as themes and sectors (agriculture, climate, employment, energy, environment, fishery, forestry, international cooperation, materials, rural development, social integration, trade, transport) will cause much pain and losses.

Scenario 2 as the combination of Scenarios 1 and 3 gives the best overall results, avoids negative trade-offs, and also meets the SDGs related to the bioeconomy by 2030. In that, its **integrative approach** is the key: neither supply-side policies nor demand-side societal action are enough, and policy coherence across sectors as well as actors (Member States, business, civil society) can be achieved only through integration.

Here, the European Green Deal is an important first step, and together with the EU budget and its COVID-19 recovery fund can align Member States and businesses in the coming years<sup>17</sup>.

Yet, Scenario 2 asks for more: A more ambitious post-2030 '**New Green Deal**' to foster the '**BioWEconomy**' on both the supply- and demand-side. This implies to successfully communicate with civil society and to support societal movements, and to be more inclusive to and collaborative with culture and arts: innovation and transformation in Scenario 2 concern both technology **and** society.

For this, there is not yet a clear pathway nor a formula to draw from – it will **require exploration** and **experiments**, exchange among pioneer actors, open reflection on possible alternatives and lessons learnt, and outreach to many for inclusion.

In slightly revising the 'leave no one behind' credo of the UN Agenda 2030, the '**BioWEconomy**' credo is 'leave no one **out**', borrowing from an African proverb:

**If you want to go fast, go alone. If you want to go far, go together.**

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<sup>17</sup> Respective alignment is also needed in international and global policies – partnering with African countries and Russia towards sustainable trade policies for the bioeconomy could be a first step.

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## **List of abbreviations and definitions**

AFOLU	Agriculture, Food, and Land Use sector
BAU	business-as-usual
CAP	Common Agricultural Policy
CHP	Combined Heat and Power (cogeneration)
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse-gas emissions
IEA	International Energy Agency
IINAS	International Institute for Sustainability Analysis and Strategy
JRC	Joint Research Centre of the European Commission
LDC	Less Developed Countries
LOHAS	Lifestyles of Health and Sustainability
LSU	Livestock Units
LULUCF	Land Use, Land Use Change and Forestry
NoE	Network of Experts
OECD	Organisation for Economic Co-operation Development
SDG	Sustainable Development Goals
US	United States of America
WB	World Bank



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## Annexes

### Annex 1: Scenario overview tables

Table 3 Synopsis of supply-side drivers and trends for the EU bioeconomy foresight scenarios

Drivers/trends EU 2050	Scenario 1: Do it for us	Scenario 2: Do it together	Scenario 3: Do it ourselves	Scenario 4: Do what is unavoidable
<b>SUPPLY</b>				
<b>Agriculture</b>	Reduction to 75% (mass-based); 70% of land under agroecology	Reduction to 65% (mass-based)	Reduction to 85% (mass-based)	Reduction to 90% (due to climate change)
- livestock production	New CAP policies (agroecology) lead to meat 50%, milk 65% of 2020 levels	Strong CAP policies (agroecology) and changed consumption led to meat 35%, milk 50% of 2020 levels	Meat and dairy 75% of 2020 levels (consumers want to change but strong lobbies prevent)	Meat and dairy maintain 2020 levels
- forestry/woody products	BAU for wood supply/use (mobilisation); BAU policies on carbon impacts with a push for "concessions" from the industry; trends in imports not affected much	Wood supply increases only moderately due to conservation practices, better use of wood and cascading, and strong C accounting also for imports	BAU for wood supply/use, but better use (demand-driven) of wood products and residues/waste (cascading); similar for imports	Significant increase in wood supply/use (mobilisation); weakly regulated with few policies on C impacts; imports increase significantly
- blue bioeconomy	Aquaculture increased by 25%, in particular, multi-trophic aquaculture; recovery of fish stocks, fishery capacities were adjusted, microalgae production received a boost	Same as Scenario 1 plus transformation of many smaller-scale fisheries to aquaculture and algae production		
<b>Energy</b>	Renewables 65%, bioenergy increased; rising import of low-GHG renewable gases (PtG, H <sub>2</sub> )	Renewables 85%, bioenergy moderately increased, strongly regulated for C impacts; little PtX/H <sub>2</sub> ("green")	Renewables 50%, bioenergy stabilised, demand-led control of C impacts; little PtX/H <sub>2</sub> imports	Renewables 50%, bioenergy increased, poorly regulated for C impacts; little PtX/H <sub>2</sub> imports
<b>Materials</b>	More imports of bio-based feedstocks	75% fewer imports than in 2020	50% fewer imports than in 2020	More imports of bio-based feedstocks
<b>Transport</b>	el. cars, hi-speed trains, low-GHG fuels	High decrease of conventional fuels; el. cars, hi-speed trains, low-GHG fuels, smart mobility	High decrease of conventional fuel in transport; smart mobility behaviour	Some biofuels, share of conventional fuel transportation slightly decreased
<b>Trade</b>	Soy imports decrease; imports of meat, fish, palm oil, sugar increase; exports of hi-quality food increase (mostly organic)	Local food from small farms preferred by consumers, strong policy support (transformed CAP + national support) imports reduced by 75% of 2020 levels, all 'sustainable & fair'	Local food from small scale farms preferred by consumers, but support policies lag; imports reduced by 50% of 2020 levels, all 'sustainable & fair'	Food exports continued to grow, pushed by increased demand. Increased imports of soybeans, fish, fruit, vegetables

Source: Compilation by the Network of Experts

Table 4 Synopsis of demand-side drivers for and outcomes of the EU bioeconomy foresight scenarios

Drivers/trends EU 2050	Scenario 1: Do it for us	Scenario 2: Do it together	Scenario 3: Do it ourselves	Scenario 4: Do what is unavoidable
<b>DEMAND</b>				
Food	Polarisation & fragmentation, the prevalence of heavy consumers (30%)	Policy supportive to low impact food systems & prevention of food wastes; consumer preference to local food	Consumer high preference for local food; low dairy, and no food wastes, but policies are weak, and lobbies get their way	Polarisation & fragmentation, the prevalence of heavy consumers (30%)
Materials	BAU = high rate of 'once-through' (e.g., clothing, electronics, furniture, packaging)	High levels of recycling; consumer preferences and policies aligned towards circularity; high innovation for biomaterials	Consumers prefer recycled materials, but slow policy development which prohibits their comprehensive and continuous availability in the markets	BAU = high rate of 'once-through' (e.g., clothing, electronics, furniture, packaging)
Transport	BAU = increasing SUV, more flights; freight: logistics increase, bulk materials decrease	Decreased demand through smart mobility; car-sharing; teleworking; bulk materials decrease	Decreasing as result of smart mobility; car-sharing; teleworking; bulk materials decrease	BAU = increasing SUV, more flights; freight: logistics increase, bulk materials decrease
<b>OUTCOMES</b>				
Economy	Competitiveness: loss in mass production, increase in high-quality; prices: energy stabilised; food increase	Competitiveness: increase in local, high-quality community-based production; food prices slightly increase, for energy decrease. Household expenditure for food, energy, and transport decreases. Local demand-side investments	Competitiveness: reduction in mass production but low rates of local, hi-quality community-based production; limited access to finance for small scale local businesses; Prices: slightly increased; food: decrease	Competitiveness gains in the export of agricultural commodities; prices: energy increase; food prices stable but strong fluctuation
Society	Polarisation between urban elites and impoverished middle class + rural areas. Obesity remains at 2020 level, minor health improvement	Harmonised living in urban and rural; better integration of immigrants; low levels of obesity and cardiovascular diseases due to better diets, walking, bicycling & garden work	Slight improvements in living standards in urban and rural; the pressure of immigration; low levels of obesity and cardiovascular diseases due to better diets, walking, bicycling & garden work	Polarisation between urban elites and impoverished middle class. Rural depopulation, land abandonment. Pressure from immigration. More fragmentation (winners and losers)
Environment	Biodiversity decrease continues; GHG reduced by 80%, LULUCF "accounted net removals" target not met; circularity objectives not reached due to rising consumption, low recycling	Biodiversity highly improved; GHG reduced by 80%; LULUCF accounted net sink target met; circularity objectives reached, high recycling; bioeconomy with lower impacts than 2020	Moderate improvements in biodiversity; GHG emissions do not achieve targets (LULUCF target maybe just met); circularity and recycling improve slightly but lack robust regulations	Biodiversity decrease continues; GHG targets not achieved (incl. LULUCF); lack of freshwater increases energy demand; more extreme weather events, circularity objectives missed (rising demand, low recycling)

Source: Compilation by the Network of Experts

## Annex 2: Participants of the Foresight Workshops

Table 5 Participants of the Foresight Workshops\*

<b>Surname</b>	<b>Name</b>	<b>Affiliation</b>
AVRAAMIDES	Marios	European Commission
BALZI	Elisabetta	European Commission
BONTOUX	Laurent	European Commission
BORKOWSKI	Piotr	EUSTAFOR
BORZACCHIELLO	Maria Teresa	European Commission
BRUNORI	Gianluca	Università di Pisa (IT)
CALIKOWSKI	Tomasz	European Commission
CHIARAMONTI	David	Politecnico di Torino (IT)
CLEMENT	Chantal	International Panel of Experts on Sustainable Food Systems
CREPY	Mathilde	European Environmental Citizens Organisation for Standardisation
DE JONG	Ed	Avantium Renewable Polymers
DIAMANTOPOULOS	Ioannis	European Commission
EDGERTON	Brendan	World Business Council for Sustainable Development
EDWARDS	Luke	BirdLife Europe
ESTREGUIL	Christine	European Commission
FERNANDEZ GUTIERREZ	Maria	European Commission
FOLLADOR	Marco	European Commission
FREITAS	Tiago	European Commission
FRITSCHÉ	Uwe	International Institute for Sustainability Analysis and Strategy (DE)
GALANAKIS	Charis	GALANAKIS LABORATORIES (EL)
GIUNTOLI	Jacopo	European Commission
GOYENS	Petra	European Commission
HEIKKONEN	Lotta	Confederation of European Forest Owners
HELLWEG	Stefanie	Swiss Federal Institute of Technology Zurich (CH)
IHLER	ØYstein	Agency for Waste Management, City of Oslo (NO)
JALASJOKI	Laura	European Network of Rural Development
KONSTANTINOÛ	Zoi	European Commission
LAMERS	Gottfried	Federal Ministry for Climate (AT)
M'BAREK	Robert	European Commission
MARELLI	Luisa	European Commission
MATTHEWS	Robert	Forest Research (UK)
MICELI	Margherita	European Confederation of Woodworking Industries (CEI-Bois)
MUBAREKA	Sarah	European Commission
MULLER	Christine	European Commission
NABUURS	Gert-Jan	Wageningen University and Research (NL)
NEAGU	Oana	Copa-Cogeca
NÍ CHONCUBHAIR	Órlaith	European Commission
PANOUTSOÛ	Calliope	Imperial College London (UK)
PARRINO	Lucia Filippa	European Commission
PHILP	Jim	Organisation for Economic Co-operation and Development

<b>Surname</b>	<b>Name</b>	<b>Affiliation</b>
PONCE DEL CASTILLO	Aida	European Trade Union Institute
PYKA	Andreas	University of Hohenheim (DE)
RAATS	Monique	University of Surrey
ROBERT	Nicolas	European Commission
SALA	Serenella	European Commission
SANCHEZ LOPEZ	Javier	European Commission
SCHOUMACHER	Cindy	European Commission
SIBBING	Lara	Ede municipality/ Wageningen Research (NL)
SOLER ESTRELLA	Alba	Concawe
VAN DEN BRINK	Anton	European Former Foodstuff Processors Association
VAN HOOF	Luc	Wageningen Research (NL)
VERKERK	Pieter	European Forest Institute
WEHRHEIM	Peter	European Commission
WOLF	Michael	European Commission
ZILLI	Rosita	Euro Coop

\* Community of Practice Workshops "Future transitions for the Bioeconomy towards Sustainable Development and a Climate-Neutral Economy Work Package 1: Knowledge Synthesis and Foresight".



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